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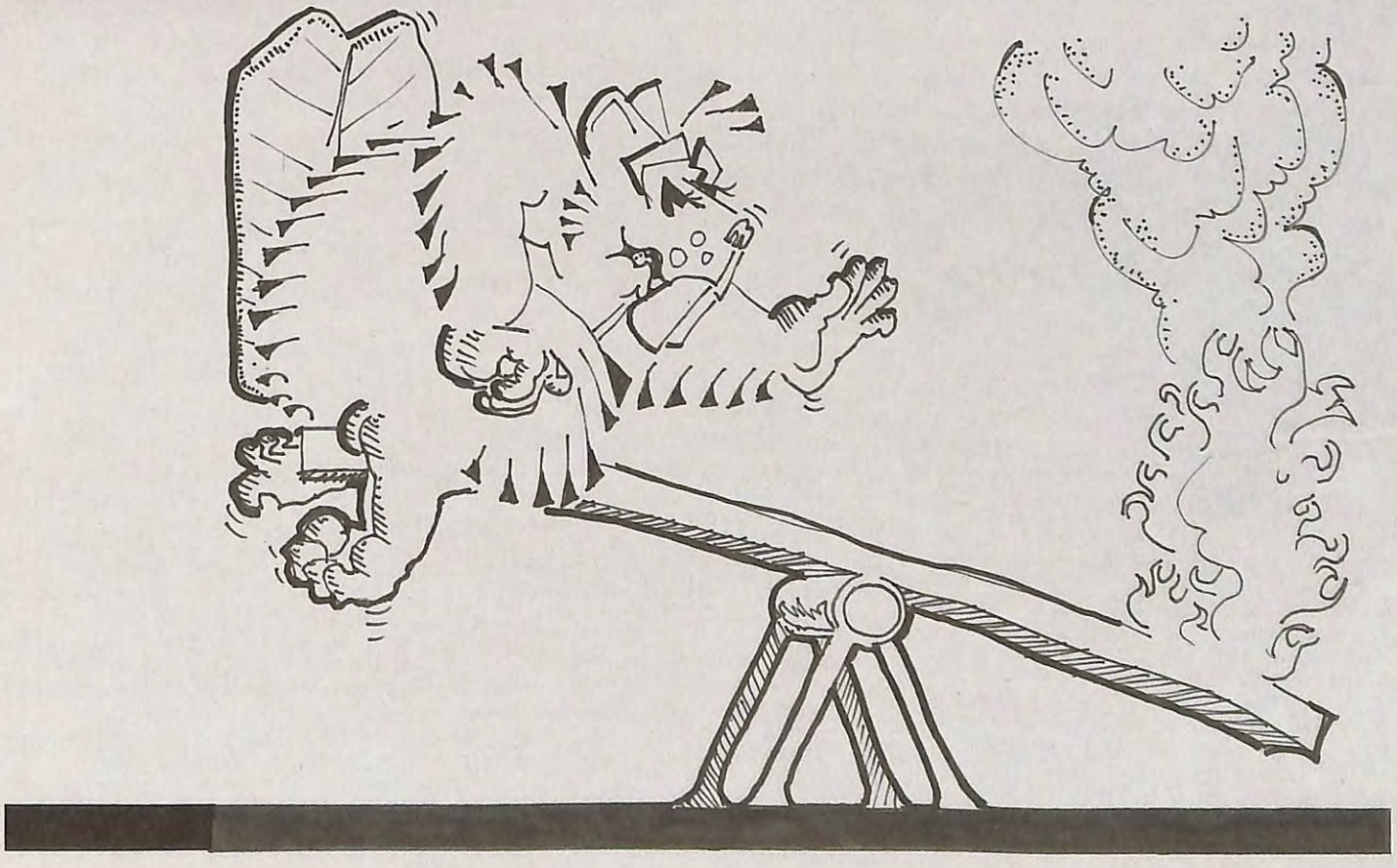
EQuilibium™ Housing: Lessons Learned



From the Editor . . .

The drivers for implementing high performance energy efficiency and moving into net zero energy homes are some owners and builders wanting to move the leading edge. These voluntary initiatives, when they are refined and proven successful, eventually filter into the mainstream and eventually are backstopped by regulations, in the form of codes and product performance regulations.

Contrary to common perceptions, regulations seldom lead. Rather, they move the rear, setting the minimums that must be met. It is important to recognize that before a threshold is set, regulators usually verify that there is a critical mass of products available before revising and setting the new rules. Yet some are impatient and want regulations to move technology more quickly.

In addition, too many consumers and industry participants consider that the codes set marks of quality construction. We need to remember that code compliance is not a mark of quality, but rather the minimum standard that must be met to be legal. They define the worst technically acceptable standard – and that has nothing to do with quality.

However, regulations are only as good as they are feasible and able to be implemented. The best or most aggressive standards are going to be meaningless if they cannot be implemented. Industry must be capable of implementing them, and the regulators must be capable of verifying that the new norms can be met.

As we have changed the way we build, and build more energy efficient assemblies, we are becoming aware that more care and attention is needed to their performance. It requires analysis of the alternate solutions, taking into account all factors to ensure that new problems are not built in – which is where research findings need to be reviewed. It also requires a reasoned review of new construction materials and building assemblies be made, looking at them from a building science perspective, and not just a legalistic review by the law department.

Contrary to common perceptions, current codes and standards contain enough flexibility to allow the use of a wide variety of construction assemblies and materials – it's just that too many designers, builders and regulators are paralysed by fear of the unknown or of perceived legal consequences.

Even today's standards would yield better performing buildings if they were applied correctly. Consistent code interpretation needs more vigilant education and training, not only at the trades level but also at the regulatory level. I continue to be amazed at the problems with code interpretations that exist – not only by builders but also designers and more worryingly, by authorities who have ultimate jurisdiction. Compliance must be improved. This may require new mechanisms to support building officials to deal with real or imagined vulnerability when confronted with new ways of building.

Richard Kadulski,
Editor

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EQuilibium™ Housing: Lessons Learned

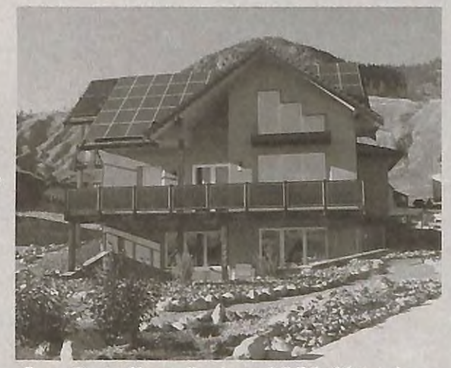
Today's leading edge housing buzz is about very energy efficient, net zero energy houses – homes that do not need to purchase energy for operation, or nearly so. It is important to understand how these high performance houses perform. The super insulation alters the thermal and moisture dynamics across the building envelope that could affect the building's durability.

Similarly, it is important to understand how well the home's mechanical systems can provide the required conditions and comfort for the occupants. Achieving extremely high performance levels may at times be a challenge in cold northern climates.

There are a number of initiatives to build these ultra-high performance homes in various parts of the world. Some are demonstration projects, such as the recently completed EQuilibrium™ initiative by CMHC. Others are initiatives that certify high performance homes that are moving in the direction of net zero – such as the new R-2000 Standard, the Passiv House, and the Platinum level of LEED for Homes, although these are at a level that could be more easily achieved today without heroic measures.

Equilibrium™ houses built through CMHC's initiative have all been occupied for a year or more. Each of the houses, in their own way, has shown different approaches and uses of new technologies for net zero housing. Monitoring results are now available for most of the houses, as some have been occupied for a couple of years. CMHC's EQuilibrium™ Housing Forum, held in Vancouver in the fall of 2012, offered some interesting insights from the homeowners of three of the homes.

For those in the industry, it offered insights we don't often see, focused on the technical issues of designing and constructing the new homes. We may understand the materials, technologies and systems used, but we often forget that the homeowner is not quite as caught up with the new stuff as we may think. It's like the techno geek who gets excited with the latest electronic wizardry that only they understand, while the average user just wants to know where the on-off switch is, and how they can use that item.


Green Dream Home: Kamloops BC EQuilibrium house

Homeowner Feedback

The owners of the Kamloops, Burnaby and Calgary (Ecohaven) EQ houses who attended the Vancouver forum participated in discussions of their houses.

Generally, they liked the design of their homes. Since they all were designed with passive solar orientation, it meant that the houses were generally flooded with light and especially welcome sunshine in the winter. They also found the homes to be very comfortable with even temperatures throughout the house.

Two of the homes (in Burnaby and Calgary) were custom homes, so the homeowners had input into the house design and had some understanding of what they might expect.

The Kamloops house was a joint project of CHBA Central Interior and Thompson Rivers University, with design and most of the construction done by trades students at the university. The house was sold by lottery.

The winners of the house already had a home in Kamloops and initially thought of selling the house and pocketing the cash, but they thought they'd experience the house for a while. They quickly discovered they enjoyed the environment and didn't want to give it up, so they sold their older house and moved into the Equilibrium home. The homeowner's daughter quickly picked up on the sustainable features of the house and is especially proud of the house.

While they were toying with the idea of selling the house, they found that realtors didn't understand the technology. They offered the suggestion that in order to get buy-in into these types of homes people need to stay in the environment so that they can personally experience it. At the

The goals of the EQuilibrium™ housing initiative:

- Develop a clear vision and approach to develop and promote low-environmental impact healthy housing across Canada;
- Build the capacity of Canada's home builders, developers, architects and engineers to design and build EQuilibrium™ homes and communities across the country;
- Educate consumers on the benefits of owning an EQuilibrium™ home and achieve market acceptance of EQuilibrium™ houses and sustainable communities; and
- Enhance Canada's domestic and international leadership and business opportunities in sustainable housing design, construction services and technologies.

end of the day, people buy for comfort, and not technology.

All the homeowners commented that the technology in these houses is too complex for a homeowner. Each of the houses had elaborate mechanical systems as well as photovoltaic panels for generating electricity, with the associated inverters and controls, as well as solar systems for domestic water heating, plus associated backup heating. The mechanical rooms ended up being a maze of equipment, complex enough to intimidate all but the most intrepid technician. Most people can't maintain appliances, so it's important to remember the KISS principle - keep it simple stupid.

What became evident to the teams in their post-mortems was that, with careful attention to design and construction detailing, the extremely small heating loads in the houses meant that very small and simple mechanical systems are all that is necessary.

Homeowners noted that utility-pricing systems, with minimum connection service charges, create a disincentive for low-energy homes. In the Kamloops house, the subdivision has a requirement that all houses must be connected to a geothermal system, maintained by a small utility, which means that the homeowners are saddled with significant service charges even if they don't take advantage of the system.

Environmentally-friendly flooring options included cork and Douglas fir flooring. The homeowners noted that this leads to floors that are too soft, and scratch easily.

The attention to low emissions finishing materials, continuous ventilation and energy efficient airtight building envelopes is important for a healthy indoor environment. All the owners commented on the superior indoor environment – they noted that it's a joy to live in their home because of the comfort. One commented that the family haven't had a cold or flu since moving into the house, and that it's a pleasure to be able to have a good sleep at home.

With low energy loads as a target, there is a move to super efficient LED lighting. However, this is a still evolving technology that remains expensive to purchase. The owners of the Eco-Haven house in Calgary found the LED uncomfortable to live with, so they don't keep the LED lights on too much.

The Builder Perspective

The builders' challenge in a Net Zero project like the EQuilibrium™ houses is to deliver an extremely efficient house in the context of pressures from many sources. Although the objective is clear, achieving the high performance goals presents challenges different from those normally faced by builders.

Net Zero energy demonstration homes are designed to address occupant health and comfort, energy efficiency and renewable energy production, resource conservation, reduced environmental impact and affordability. These energy-efficient grid-connected homes with low environmental impact aim to produce as much energy in a year as they consume in the form of heat, light and power.

EQuilibrium housing features on-site renewable energy systems to provide clean energy to help reduce annual consumption. These can include photovoltaic panels to generate electricity, and other renewable energy systems such as solar hot water and geothermal energy systems to produce reliable, low-cost, environmentally friendly energy.

Performance expectations and objectives are set out. These include detailed calculation procedures so that evaluation is consistent.

Performance Requirements

First, there is a requirement that the building envelope achieve a minimum EnerGuide rating of 82 with standard heating and ventilation equipment before any credit is given to high performance equipment or renewable energy systems.

Secondly, reductions in base electrical loads are considered – this is loads for lighting and appliances.

Thirdly, domestic hot water use reductions are considered.

Fourthly, the home's cooling load is considered, and includes space cooling in the design, if it is required.

After these elements are in place, renewable energy systems and combined heat and water systems can be considered if they form a part of the design.

The objective is to achieve a home that, on an annual basis, will generate as much energy as it would use over the year.

Collaborative Design

An important element is to get all members of the project team together at the design stage to develop and fine-tune the design. These collaborative design exercises, also referred to as charretes, harness the talents of all parties. This gets the buy-in of all participants in the design and construction and can be effective at achieving savings.

Charretes are a requirement of the LEED program, as they have proven to be an important way to develop designs. It's recognized that all participants have something to contribute, and it's a way to reduce conflicts between competing trades from the outset.

Design charretes are not common in the residential sector, especially for a house, but nevertheless are an important and useful tool. Homebuilders can benefit from such an exercise and it can have the benefit of not only minimizing conflicts during construction, but offer a way to improve the construction process and reduce costs.

Charrete Challenges

The EQuilibrium teams all found the charrete useful, even though it presented challenges.

It was noted that to be meaningful, the right people must be at the table – people that can contribute, be open to new ideas, and that will have an active on-going involvement with the project. It is best to have some persons that will also be on-site during construction, and not just back-office personnel. Participants need to listen carefully and fully process the information discussed before decisions are made.

Ecohaven, Calgary EQuilibrium house

Complicating the motivation to participate in such a design exercise is that most houses are effectively prototypes, especially in small market areas and in much of BC, where there are few large tract projects. Builders in larger tract subdivisions have the opportunity to fine tune designs and details that can be applied in a number of repetitive designs.

Some of the challenges noted were that trades should be active participants in the charrete, but it was noted that they might not participate in such an exercise unless they have a contract in hand. This is important because in general, key trades, such as mechanical contractors, are often left out of the decision-making process and have to make decisions for their work around what's been done by others, often leading to poorly laid out or designed systems, or systems improvised on site. Careful design in advance can get good results and minimize conflicts on site.

One common issue was related to mechanical systems. A common problem that mechanical contractors face is that often there is no space provided for their equipment. The physical needs of mechanical systems are rarely on the horizon of home designers, while homeowners and interior designers focus on interior decor and try to maximize usable interior space. Mechanical rooms and duct chases become afterthoughts, with the result that heating, ventilation and air conditioning ducts often end up being run outside the heated envelope of the house, through attics, resulting in lower performance as the ducts are rarely properly air sealed or insulated to the same level as the ceiling insulation. In addition, the multiple penetration points of ducts through the ceiling air barrier create more potential air leakage paths as these will be difficult to properly air-seal.

Some felt that the group exercises created a design team that was too large to make effective decisions. There was some uncertainty about who makes decisions when they need to be made.

However, this may have been a reflection of the teams being unfamiliar with the charrete process.

Donor Influence

Since these homes were meant to be special demonstration homes, showcasing new design strategies and technologies for Net Zero energy housing, they relied on sponsors and contributions. This led to situations where decisions were driven by donor contributions and influence, and not necessarily on economic or value index basis, or what may have been the technically preferred option to take. In some cases, it means more materials, products and systems are incorporated than necessary. In such situations, it becomes a matter of justifying the use or showcasing a given product or technology.

One builder noted that with high insulation levels, the weight of the insulation imposes additional structural loads. The R-80 insulation installed at their house required the use of OSB on the ceiling to support the insulation, as the drywall itself was not considered capable of holding the weight of the insulation.

Photovoltaic Panels

Because the object of the demonstration was to build Net Zero houses, it inevitably requires the use of photovoltaic panels. As one builder said, at the end of the day anyone can build an EQuilibrium house – you just need to buy and install more PV panels.

Prices for PV have come down drastically recently. However, caution must be exercised when using PV. There are design issues about their location – shading of panels, even a small portion, can affect the output. Typically, PV inverters are used in series, which work well with no shading. However, unlike solar thermal panels (as in solar water heating), if a portion of a PV array is in shade, the output of the entire system will be compromised unless the panels are hooked up in a manner that takes this into account. Micro inverters are needed to segment the array into small sections, but there are limits to the size – they need to connect at least six or seven PV panels. Small systems favour the use of these micro inverters, but the available technology hasn't kept up with the need yet.

Snow cover on panels can provide quite a bit of shade the PV panels, and it doesn't slide off as quickly and completely as is often expected.

It was noted that the majority of EQuilibrium houses are under-performing with respect to predictions. Most PV predictions will be ±20% accurate, due to variations in weather and minor installation issues.

As with many technologies, there is also the added complication of standards and inspections. There still are only a small number of trained PV system installers, and regulators have a difficult time knowing how to deal with these systems. In BC, grid-connected PV systems require the use of CSA certified equipment, which is a challenge for new technologies.

Rainwater Harvesting

Rainwater harvesting is becoming a favourite option to reduce water consumption. However, as one noted, it's an interesting option as long as there is enough rain for it to be meaningful. It was noted that a more useful technology to pursue would be the use of grey water, which requires some treatment.☼

Urban Ecology

Urban Ecology is a new, two-storey semi-detached duplex with basement located on an infill site in a rejuvenated downtown area of Winnipeg, Manitoba. It is unique because it incorporates an EQuilibrium™ demonstration home on one side, and an R-2000 home on the other side.

This project was developed by the Winnipeg Housing Rehabilitation Corporation (WHRC), a non-profit developer and manager of affordable housing in Winnipeg. It also shows that you can incorporate very high performance and net zero energy construction in modest housing.

Each unit has a 1,287 sq.ft. (119.5 m^2). floor area. The main floor in each has an accessible, open concept design with living room, galley kitchen, dining room and two-piece barrier-free bathroom. The second floor includes a master bedroom, two small bedrooms, and a three-piece bathroom. The basement is unfinished.

The high performance building envelope includes a super insulated envelope: double stud wall (R-65 nominal), R-80 attic, R-40 foundation and R-20 insulation under the basement floor, and triple-glazed windows.

In addition to the passive solar space heating utilized by both units of the duplex, the EQuilibrium™ demonstration home has a 4 panel flat plate thermal solar collector system that provides hot water for in-floor hydronic space heating in the basement. If required, the water temperature can be boosted with an in-line electric heater.

The solar collector system also provides the domestic hot water that is supplemented by a heat pump water heater that takes heat from air in the basement to the water in the hot water tanks as required, with an electric back-up heater. In addition, a drainwater heat recovery system has been installed and is predicted to decrease the domestic hot water heating requirements in this unit by 20%.

The unit includes a grid connected photovoltaic (PV) system on the EQuilibrium™ side.

Urban Ecology, Winnipeg. EQuilibrium unit is on the left, R-2000 unit is on the right.

Letters to the Editor

I started using the airtight drywall approach (ADA) more than twenty years ago. I had no problems when I used ADA to build my own house in Burnaby. Over the years we've used both the ADA and poly vapour barrier approaches when doing renovations.

I am now rehabilitating an older house in Port Coquitlam for my daughter and wish to use the ADA. I provided a copy of a factsheet from Building Science Corporation (*Air Barriers – Airtight Drywall Approach for All Climates, Sealing Perimeter of Drywall Assemblies – BSC Information Sheet 401*) to the building department. To my surprise, the plan reviewer said she could not accept the document because it is an American document, and the building inspector said I would need to have a registered professional monitor this complicated process.

Complicated? Really??? What can we do to get the message through to officials?

JV, Vancouver

Unfortunately, lack of knowledge or ability to reason with building science principles has no boundary, and we are bound to encounter it in all sectors of the industry. The building code clearly separates air barriers from vapour barriers, to permit whatever approaches a builder and designer choses to use in a building. Your situation is disturbing as the Homeowner Protection Office (HPO) in BC has published a number of documents that detail different but appropriate and acceptable construction details.

The HPO has published ***Building Envelope Details Guide: Part 9 Residential Construction****, one of several detailed publications they have produced. The guide is an excellent, fully illustrated resource document for homebuilders, designers and trades (and building officials) that shows step-by-step construction details and descriptions, many with full colour 3-D images. The guide presents the details for three main air barrier approaches: sealed polyethylene air barrier, airtight drywall air barrier, and exterior house-wrap air barrier.*

This easy-to-use guide provides practical information on the design and construction of the building envelope for new homes constructed in accordance with Part 9 of the 2006 British Columbia Building Code. Although this is targeted for the BC industry, the document is an invaluable resource for designers and builders in any part of the country. (available from the HPO – information: www.hpo.bc.ca)

Re Spray Foam Insulation Properties (Solplan Review 167, November 2012)

I took an interest in reading your November article on spray foam insulation.

I believe it is important to note that CCMC evaluation reports require that manufacturers list the percentage of water absorption associated with their low-density (open cell) spray foam products. This value can be related to how much moisture the spray foam could entrain and thus suggests what role the foam will play in assemblies subject to moisture-induced deterioration. The lower the water absorption value, the less the spray foam acts as a sponge, and the higher the likelihood that any water in an assembly will avoid the foam and seek a low point via gravity. This means that any water leaks in an assembly would be found much easier and quicker.

John Broniek, Senior Engineer,
ICYNENE Inc.

Canadian Home Builders' Association

Technical Research Committee News

History of Canadian Housing Research: The Mark Houses

The technology we live with (and can't live without) today is the result of a long evolutionary process aided by formal and informal research.

The quality of Canadian housing, recognized internationally, is the result of such research. Work done at the National Research Council and CMHC has had a big influence on how we build today. Homebuilders played a key role in some of the research activities. Between 1957 and the early 1980s, the predecessor of CHBA, with the participation of the NRC and CMHC, undertook the construction of a series of sixteen research house projects. These were known as the "Mark" research houses. A total of about 200 units were built, as some projects involved multiple houses. Each project focused on a couple of issues.

Affordability

Mark I house in Hespeler, Ontario (1957)

The first research house, the Mark I house focused on housing affordability. It was built in Hespeler (Cambridge) Ontario in 1957, and a companion house was built in Dartmouth, Nova Scotia.

One objective was to demonstrate that a low cost, structurally sound house could be built. Another objective was to allay the widely held misconception that the only way to produce a low cost house is to reduce the size of the unit and the quality of the materials and workmanship.

Costs were reduced through attention to design, using new building techniques, proper planning, scheduling, and supervision, a practical building code and standardization of parts and materials on a modular system. No attempt was made to cut costs on plumbing, electrical work, plastering or painting.

The Mark 1 house was a three-bedroom 864 ft^2 bungalow (with a 24'x36' footprint). It was shown to provide the same living space as a brick house 925 ft^2 gross area. Today this may seem like a small house to many, but in 1957 that was a typical floor area for modest market houses.

In 1957 dollars, the Mark 1 house would have a selling price of $8,000. (that includes builder's costs, overhead, sales expenses and profit). That is equivalent to $65,040 in 2012 dollars.

An upgraded model with 4 closet doors, ribbon windows, wall tile around the bathtub, a porch, carport, asphalt drive and decorating would add $723 more to the cost. The average annual income in 1957 (in the manufacturing sector) was $3,609 for men and $1,974 women.

Construction features

The foundation was an insulated, two-foot high heated crawlspace, built with 8" concrete walls without a footing. A 4-mil poly vapour barrier was installed between the batt insulation and the wall and covering the gravel floor of crawl space. A central poured concrete foundation wall supports floor joists at mid span.

The floor system was 2"x8" joists at 16" on centre (span was 12 feet) with a continuous 1"x4" strip bridging at the mid-point of the joist span. A single joist was used under partitions. Half-inch thick painted plywood was the subfloor as well as finished floor in the living room and bedrooms. Linoleum tile was the finish in other rooms. The edges of the plywood were supported by 1"x2" strips notched into the top of the joists.

The exterior walls were 2"x4" at 16" on centre studs in prefabricated panels. 3/8" thick Fir plywood was used as combination sheathing/siding. Joints were covered with 1"x2" vertical battens at 16" on centre. Insulation was 3" fiberglass batt with a 2-mil poly vapour barrier. The interior was ½" lath and plaster. Plaster was chosen over drywall to make any settlement cracks more apparent because of concerns about eliminating the double joist under the partitions.

The bathroom window was eliminated and replaced by a fan

The 3:12 pitch roof was framed with 2"x6" rafters at 24" o/c with 2"x4" collar ties at the mid point. The ceiling joists were 2"x6" ceiling joists, with a double top plate on the walls. The 2"x8" ridge was unsupported. The roof sheathing was 3/8" fir plywood with 1"x2" edge supports notched into the rafters. The ceiling insulation

Those who fail to learn from history are doomed to repeat it.

Winston Churchill

was a 3" batt fiberglass between the ceiling joists, with a 2-mil poly, vapour barrier on roof deck with asphalt shingles. Attic ventilation was two louvers in the roof and ¾" holes drilled at 4" o/c in the eaves and no vents in the end gables.

Interior partitions were shop prefabricated 2"x4" studs placed on their flat, and finished with ½" lath & plaster. Two months after completion only 2 hairline cracks were spotted, and ten months later a few very fine cracks were noticed.

Doors were pre-hung units. The living room window was a single glazed, fixed unit, while all other windows were sashless, single glazed, horizontal sliders, which were becoming popular at the time. After one year it was noted that there was extensive condensation and/or frosting on the inside of the windows which impaired the seal and operation was impossible due to ice in the bottom track

Heating and Ventilation

The crawl space was designed to serve as a giant plenum for a reverse-flow 75,000 BTU furnace. Warm air from the furnace is distributed to the crawl space by 4 stub ducts extending 8' out from a dropped plenum, and warm air enters the living area through conventional floor registers around the perimeter of the house.

Dartmouth Mark House

, The Mark 1 exercise was repeated in Dartmouth, with an identical house design, but it was site-built, and financed by the Bank of Montreal rather than CMHC. It generated a lot of public interest and sold quickly. Twenty-five similar houses were built, but the roof slope was changed to 4:12 to allow the use of conventional shingles.

Fifteen more houses were built but CMHC required that modifications be made to bring the houses to NHA Standards. These included tiled floors throughout, the floor sheathing thickness increased to 5/8" from ½", wall sheathing increased to ½" from 3/8", and the floor joists were doubled under the partitions. The crawlspace foundation was changed to 4' high foundation walls on footings. These changes added another $660 cost per house (an 8.25% increase).

What were the Results?

Condensation was noted on the poly in the crawl space as well as between the poly and the concrete wall.

In 1957 a lot of work was done on site. Unlike today, there were fewer manufactured components. For example, most windows were site-built. Plywood only started being used in construction after the Second World War. The first CSA plywood standard was only published in 1953.

Some damp and mouldy areas were noted on the ceiling – mostly near the intersection of walls and ceilings and in closet areas. These areas typically are the coldest areas with the least amount of insulation, because of the thermal bridging.

It was also noted that occupants refused to try to correct the situation by means of window and door ventilation. The report also noted that these houses are small, tightly constructed houses, sited on poorly drained sites with no drainage tiles around the footings. In addition, the occupants removed or rearranged poly over the crawlspace floor.

Occupants reported low fuel bills based on "high combustion efficiency", the size and tightness of the houses, the absence of a basement, and higher relative humidity which permits lower thermostat settings for the same comfort". Overall, it was noted that problems were no more frequent than in conventional houses.

Some of these comments may seem strange and quaint today, but we need to consider that this was more than 50 years ago. At the time, these were significant steps.

The Mark II House

The follow-up project, the Mark II house was to be built in Calgary. It was a similar design with modifications in the specifications. The project team noted that conventional construction systems were over-designed when subjected to proper engineering analysis. It was observed that significant opportunities for lowering costs could come through the use of materials and techniques not then approved by codes but that, nevertheless, would provide a sound structure. They proposed the use of new materials and methods that did not meet CMHC or NBC requirements in force at the time.

However the radical departures from conventional construction practices led to an unexpected difficulty: no municipality would allow the house to be built within its borders – they were unwilling to waive their building bylaws to accommodate the proposed innovative techniques. As a result, the plan to build 5 houses, one in each climatic region across the country was reduced to just one house built outside Calgary.☼

Calculating Effective R-values

Until recently, energy codes and construction practice have relied on nominal R-values. It has been the shorthand way to express building envelope properties. It's always been considered that when you put an R-20 batt into a 2x6 stud wall, you have an R-20 wall.

Conventional framing practices mean that a large amount of exterior surface area of the walls is framing, so thermal bridging can have a big impact on the effective performance of a construction assembly. A conventional 2x6 stud wall will actually have an R-value that is closer to R-16 or less, depending on the framing practices, the size of the wall, etc.

Section 9.36 of the National Building Code now requires the use of effective R-values, so that thermal bridging will be considered. Effective R-value calculations consider all components of the assembly – from the exterior boundary air layer immediately adjacent, to the surface of the surface material that contributes a small but measurable amount of thermal resistance, across all materials in the assembly to the interior boundary air layer. And those small boundary air layer resistance values vary with the orientation of the assembly – a value on the wall is different from the ceiling or a cold floor element.

In engineering terms, it's the isothermal-planes and parallel-path flow methods, which are described in the ASHRAE 2009 Handbook of Fundamentals.

For an assembly containing only continuous materials, such as an insulated floor slab, you only need to add up all R-values of all the materials and that gives you the effective R-value.

For a wood frame assembly like a wall, one needs to calculate the effective thermal resistance of all layers with continuous materials used, and the effective thermal resistance of the framing portion, and then average the two using the following equation which is taken from the parallel-path flow method described in the ASHRAE 2009 Handbook of Fundamentals. The formula is:

$$R_{effective} = \frac{100}{\frac{\%\text{ area framing}}{\text{R-value framing}} + \frac{\%\text{ area insulation}}{\text{R-value insulation}}}$$

The values used in calculation must not be rounded – only the final result is rounded to the nearest significant number.

When calculating effective R-values, it is particularly important to use appropriate values for the framing. Detailed analysis of current practices has shown that in wall framing for a stud wall at 16" on centre, the framing accounts for 23% of the wall surface area, while for 24" spacing it is 20%.

.With advanced framing, it drops to 19% for studs at 16" on centre, and 16% for 24" spacing.

The "advanced framing" refers to framing techniques designed to reduce the amount of excess framing lumber and thermal bridging and thus improve the energy efficiency of a building assembly, without compromising structural needs. There are a variety of advanced framing approaches, and some require that some framing components be insulated or eliminated, in which case a detailed calculation of the actual % area of framing is needed. The framing percentage values listed in the building code for advanced framing are based on assemblies with insulated lintels or framing designed without lintels, corners with one or two studs, no cripple or jack studs, and double top plates.

In the example we're showing, a 2x6 advanced framing wall with studs spaced at 24" would have an effective R-value of 17.99 (RSI 3.17).

Sample calculation for a wood frame wall 2x6 studs 16" on centre (RSI values ($m^2 \cdot K$)/W)			
Outside air film			0.03
Wood siding			0.14
Sheathing paper			-
Plywood sheathing (12.7 mm)			0.109
Stud (2x6)	RSI_F = 1.19	% area of framing = 23%	$RSI_{parallel}$ = 2.36
Insulation (R-19)	RSI_C = 3.34	% area of cavity = 77%	
Polyethylene (vapour barrier)			-
Gypsum (12.7 mm)			0.077
Interior air film			0.12
Total assembly			RSI_{eff} = 2.95 (R = 16.75)
To convert RSI values to R multiply RSI by 5.678			

Government Minister Faces Judicial Review For Ditching Energy Efficiency Regulations

It's not something we'll see in Canada, but the UK Communities Secretary, Eric Pickles, is facing a judicial review for ditching energy efficiency rules for home renovations and additions that, it is estimated, could have saved the UK economy £11 billion pounds.

The original proposal was that, when major additions or renovations were to be done, 10% of the value would have to be spent on improving the energy efficiency of the original building. According to government estimates, in addition to savings due to lower energy costs, it would have led to more than 130 million tonnes of CO2 reductions.

The proposed energy efficiency regulations had been through public consultations and various polls indicated that nearly 66% of the public were in favour.

There was no explanation for the minister's decision to reject the changes that he had previously championed.

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Great Canadian Reno-Demo Update

Regular readers may recall the accounts about the renovations at your editor's home in North Vancouver. This was a whole house makeover. Changes included a small addition, gutting the house, reconfiguring some rooms, upgrading insulation, replacing windows with new high performance triple-glazed units, and air sealing.

The work has been completed for more than a year, and as the dust has settled, it's possible to assess the results.

EnerGuide Rating: 82

Before the renovation started, much of the home's characteristics were original, as little had been upgraded since the house was first built in the early part of the 20th century. The EnerGuide rating of the house before the renovation was 58, and went to 82 on completion.

When work was started, the house was not airtight at all – with an air change rate of 11.88 air changes @ 50 Pascals. Although a major effort was made to air seal the house, and the house was insulated with spray foam insulation, the blower door test at completion showed the house was at 4.17 air changes.

This was a significant improvement, but it does point out the challenges of air sealing older homes, especially homes that are articulated. This house has dormers, cold floor areas, vaulted ceilings and portions of the house that were not disturbed during the renovation, so it was difficult to attend to all potential air leakage points.

Noise attenuation

Spray foam insulation was used throughout the house. Exterior 2x4 walls were clad with 2" CodeBord® extruded polystyrene exterior wall insulating sheathing (XPS), and Icynene MD-C-200 2-lb polyurethane spray foam insulation on the interior.

The 2-lb foam plus the XPS on the exterior forms a very well insulated wall, but the materials form a rigid diaphragm. The house is located on a secondary arterial road with a bus route, so there is a reasonable amount of traffic. Although the house is well insulated, and the windows are airtight triple-glazed units, the traffic noise is not shut out as much as one would think.

The use of a more flexible insulation on the interior – such as an open celled ½ pound foam or a fibrous insulation would have aided in sound attenuation, and provided a more satisfactory result.☼

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Energy Answers

Rob Dumont

How was the Saskatchewan Conservation House designed?

The Saskatchewan Conservation House, built in 1977, was a landmark energy efficient house built in Regina. It featured a number of firsts: the first really well-sealed building envelope (0.8 air changes per hour at 50 pascals); insulation levels (R40 walls, R60 ceiling, R 35 floor) far in excess of conventional homes in Regina -- R12 walls were common at that time in conventional homes; an air-to-air heat exchanger using polyethylene heat transfer surfaces; and a drainwater heat exchanger.

Figure1. South-facing view of the Saskatchewan Conservation House (1977)

I was a participant on the design committee. Although the word was not common at the time, a charrette-type process was used to develop the design. The design team included several key persons. Bob Besant of the University of Saskatchewan was heavily involved in the design of the active solar thermal system, the air-to-air heat exchanger, the drain water heat recovery unit, and the overall thermal modelling of the house space heating system Harold Orr of the National Research Council's Division of Building Research, developed the air tightness details and later installed the air-vapour barrier in the house along with Jerry Makohon of the NRC. David Eyre of the Saskatchewan Research Council was the project manager. Hendrik Grolle of Regina was the house architect. I was a grad student at the time, and helped out with the drainwater heat exchanger and the house energy monitoring using a data logger. Other committee members included Gary Marvin of CMHC, Ken Scherle of the Saskatchewan Housing Corporation, Leon Katz of the Saskatchewan Science Policy Secretariat, Steve Hardy of the electrical utility (the Saskatchewan Power Corporation), Bill Husband, Dave Jennings and Deryl Thompson of the Saskatchewan Research Council, Peter Catania of the University of Regina, Bill Gibbons of the Housing and Urban Development Association of Canada, and Dennis Rogoza of the Office of Energy Conservation of Saskatchewan Mineral Resources.

How did the design evolve?

One of the committee members initially suggested that we should just use the Arkansas House, an energy-efficient design developed for the Arkansas climate, as the basis for the house. That house, I recall, featured modestly improved wall insulation such as R-20 walls, improved attic insulation and orientation of the house for passive solar gain.

Another committee member used an analogy from the struggle against polio to bolster the case for more aggressive energy measures. In the scientific research world, there is a phenomenon known as "iron lung-ing", or focussing on very small improvements. Here is a bit of background. In the fight against polio, iron lungs were used to help those severely afflicted with poor breathing. Some researchers advocated developing a lighter, improved, more portable version of the iron lung to help those afflicted. Fortunately, the more radical approach, that of developing the Salk vaccine to prevent polio, was adopted. A true cure for the immense problem of polio was developed, and polio has been wiped out in all but a few countries in the world.

And, fortunately as well, members of the design committee for the Conservation House opted for aggressive energy efficiency measures. This was a tipping point for the design.

What do you consider to be the greatest success of the Conservation House?

I consider the greatest success was the demonstration of how well, radical, for the time, energy conservation measures would work in such a cold climate. I keep reminding people that less than 1% of the world's population live in as cold a climate as the Canadian prairies. For the Conservation House on an annual basis, almost half (47.2%) of the space heating was provided by the internal heat gains from appliances and lights (42%) and from people 5.2%. Passive solar provided 31.3%, and the remaining space heat was provided by the active solar system and back-up electricity. The space heating conservation measures included superinsulation, air tightness, and heat recovery on the ventilation air.

And what do you consider as the least successful measures used on the House?

It is now about 36 years since the Conservation House was built. Hindsight is always 20-20.

The vacuum tube solar heating panels were problematic. The vacuum tube panels were chosen for their high efficiency, but they have a big problem in that snow will accumulate on the panels and not melt or slide off in cold weather even though the panels were at a tilt angle of 70 degrees to the horizontal. In Figure 2 a picture tells the story. Regina is in the snowbelt, and snow is usually around from early November until early April each winter. As can be seen, snow covers a good proportion of the panels. A roof overhang was incorporated over the top of the collectors in an attempt to reduce the snow accumulation, but the overhang was not completely successful. Some pigeons that do not acknowledge the significance of this house insisted on roosting on the overhang and defecating on the solar panels. The roof overhang was later removed after the house was sold.

Because of the problem with snow accumulation and the fact that the manufacturer was no longer supporting the product, the solar panels were removed by the second owner.

The exterior insulating shutters on the south facing windows on the main floor would vibrate in some wind conditions and shake the house. (See Figure 1.) After the house was sold, the homeowners removed the shutters and replaced the double-glazed windows with triple-glazed windows. Insulating shutters are an excellent theoretical idea for windows in cold climates, but the practical problems of actuators and air sealing of the shutters is considerable. Most designers now settle for triple-glazed windows with high solar heat gain factors (0.55 or higher) for the south windows.

The aesthetic design of the front (street-facing) side of the house was lacking. A picture of the north wall of the house is shown in Figure 3.

Figure 2. Snow accumulation on the Vacuum Tube Solar Panels

The only penetrations of the north wall are the two air to air heat exchanger vents on the upper part of the wall, two vertical windows and the front door for the house. Note also that there were no windows on the west wall. Evergreen trees were planted on the north side of the house.

The appliances chosen for the house were not very energy efficient. In 1977 there were no really energy efficient refrigerators, freezers or clothes washers on the market. In addition, there were no compact fluorescent lamps or LED lamps available. Fortunately these are all now readily available.

Figure 3. North Facing Facade of the Conservation House

The drainwater heat exchanger was not very efficient and required periodic internal cleaning. Fortunately several manufacturers now make low maintenance units that do not require cleaning.

On the 100th anniversary of the founding of Saskatchewan, a selection was made of the top 25 scientific achievements in the province. The Saskatchewan Conservation House was in the top 25.

"Example is the school of mankind. It will learn at no other." So wrote the English philosopher Edmund Burke. The Conservation House was a great example.

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NRC·CNRC

Using VIPs to achieve highly insulated buildings

By Dr. Wahid Maref

Previous Solplan articles have reported on the potential for using Vacuum Insulation Panels (VIPs) in building construction, and obstacles to their wide-spread use. Although VIPs provide insulating values up to R-60 per inch, the main obstacle to their use in buildings has been the risk of puncture damage during construction, and the subsequent loss of insulating value. NRC Construction has completed research that advances the prospects of significantly increasing the insulating value of retrofitted walls using VIPs.

Like other insulations, VIPs can be used in the retrofit of existing buildings on either the interior or the exterior. They can also be used in new construction. For retrofitting, adding thermal insulation on the exterior has the advantage of minimal disruption to occupants and the ability to minimize costs, particularly if the energy retrofit measures are coordinated with other façade rehabilitation work. Adding thermal insulation on the exterior of the existing shell can increase the overall R-value and the airtightness of the wall assembly, as well as reduce thermal bridging due to structural elements. This results in higher energy performance and thermal comfort, and lower operation costs.

Using NRC Construction's Field Exposure of Walls Facility (FEWF), researchers tested two VIP configurations to study the effect of energy retrofit strategies on energy performance and durability. Both configurations had VIP panels sandwiched between rigid insulation boards. One method used panels that were clipped to the sheathing (Figure 1).The other used panels with tongue-and-groove joints (Figure 2) that were attached to the test wall by screws located along the panel perimeter.For both methods, the perimeter of the panels was visibly obvious and therefore, with some care, strapping or cladding could be attached without damaging the VIP insulation.

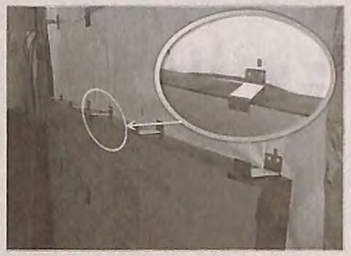

Figure 1:VIP panel sandwiched between rigid insulation boards and clipped to the sheathing.

The tongue-and-groove arrangement was easier and faster to install but had slightly lower thermal performance compared to the clip-on method.

For both VIP walls, the additional insulation increased internal wall temperatures, thereby reducing the risk of the presence of moisture and possible damage. The addition of 55 mm of wall depth added a nominal R-value of about R-48, giving overall R-values of about R-68.

The hygrothermal tool hygIRC-C was used to determine the energy savings due to retrofitting the wood-frame wall systems with VIPs.It showed that the clip-on method had additional thermal resistance of R-2, due to the effect of the air space between the insulation and the exterior cladding. The attachment methods and cladding used did not imperil the VIPs and the sandwich configurations facilitated changing a panel, should one be found to be faulty at the time of installation.

By comparison, adding 50 mm (2 in.) of rigid insulation alone to the exterior, as in the case of undertaking a typical retrofit, added R-10 to the original R-20 wall to give a total nominal R-value of 30 – less than half the nominal R-value of the VIP retrofitted walls.

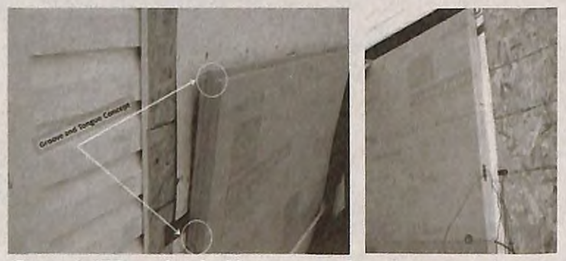

Figure 2:VIP sandwiched between rigid insulation boards and screwed to the sheathing at the tongue-and-groove joints.

During this project, there was one failed VIP. Panelization of the VIPs made it easy to remove and replace the unit. This highlights the importance of careful installation, having a means to detect a failed VIP and having an easy way of replacing a damaged VIP.

VIPs have tremendous potential to improve building thermal performance. Although Vacuum Insulation Panels are still considerably more expensive than other established technologies, it is anticipated that improved manufacturing capacity and methods are likely to decrease their cost. This project showed that it is possible to use VIPs to retrofit existing wood-framed wall systems and, thereby significantly increase insulating values. It also demonstrated that such systems can be assembled and installed in a way that protects them during installation. ☼

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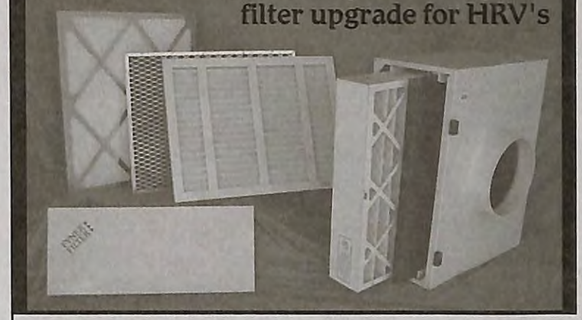

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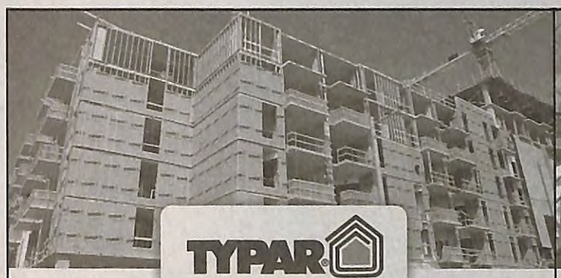

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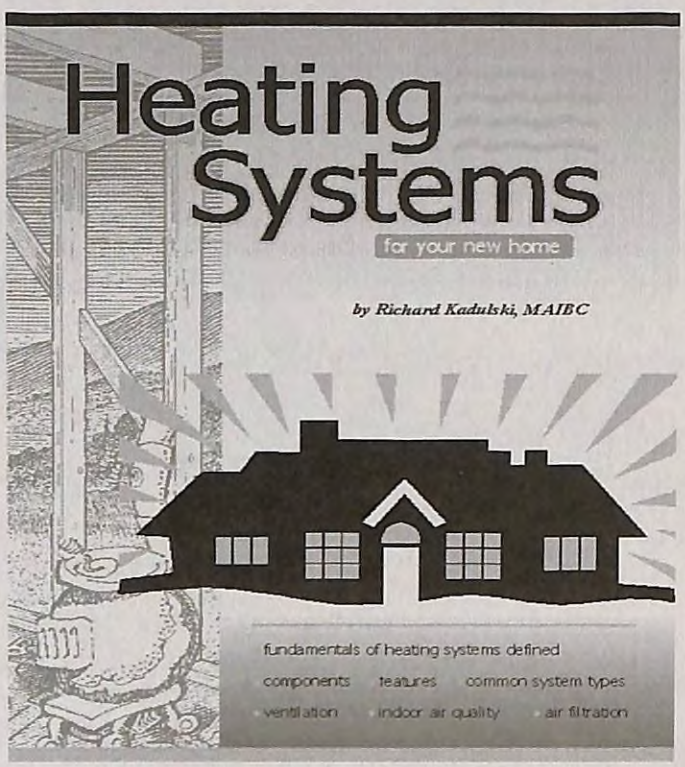
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